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ORIGINAL ARTICLE

Walking Performance and Muscle Strength in the Later Stage Poststroke: A Nonlinear Relationship

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Abstract

Objectives: To evaluate the relation between muscle strength in the lower extremities and walking performance (speed and distance) in subjects in the later stage poststroke and to compare this with normative data.

Design: A cross-sectional observational study.

Setting: University hospital department.

Participants: Subjects poststroke (n=41; 31 men, 10 women) with a mean age of 59±5.8 years and a time from stroke onset of 52±36 months were evaluated. An urban sample (n=144) of 40- to 79-year-olds (69 men, 75 women) formed the healthy reference group.

Interventions: Not applicable.

Main Outcome Measures: Muscle strength in the lower extremities was measured with an isokinetic dynamometer and combined into a strength index. Values for the 30-meter walk test for self-selected and maximum speed and the 6-minute walk test were measured. A nonlinear regression model was used.

Results: The average strength index was 730±309 in the subjects after stroke compared with 1112±362 in the healthy group. A nonlinear relation between walking performance and muscle strength was evident. The model explained 37% of the variance in self-selected speed in the stroke group and 20% in the healthy group, and 63% and 38%, respectively, in the maximum walking speed. For the 6-minute walk test, the model explained 44% of the variance in the stroke group.

Conclusions: Subjects in the later stage poststroke were weaker than the healthy reference group, and their weakness was associated with walking performance. At the same strength index, subjects walked at lower speeds and shorter distances after stroke, indicating that there are multiple impairments that affect walking ability. Treatments focused on increasing muscle strength thus continue to hold promise.

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Stroke is the second most common cause of death worldwide[1] and the most common cause of long-term adult disability.[2] Despite intensive therapy during the first 6 months after stroke onset, a large number of subjects are left with significant disabilities.[3] Approximately 22% of the people who have survived a stroke are unable to walk without assistance, and 26% are dependent on others in activities of daily life.[4] One possible cause of these disabilities is the muscle weakness commonly seen after stroke. Recent evidence suggests that both lower extremities after acute stroke seem to be affected as compared with controls.[5,6] Reduced muscle strength has also been recognized as a limiting factor in stroke rehabilitation.[7]

Increased strength in the lower extremity muscles (hip and knee flexors and extensors, ankle dorsal and plantar flexors) has been shown to be associated with improvements in mobility such as walking performance,[8-11] ability to balance,[10] and stair climbing.[11]

An understanding of how impairments in muscle strength relate to activities such as walking short and long distances can be of use to therapists when they examine and plan interventions to limit or decrease functional limitations. Walking speed and endurance, such as the 10-meter walk test[12] or the 30-meter walk test[13] and the 6-minute walk test (6MWT),[14,15] have been used in both clinical practice and research and are also often used to predict and assess

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community ambulation.[16] There is some evidence that measures of different muscles in the lower extremity combined are more closely related to functional outcome than measures of single muscles.[17,18] Previous studies of subjects after stroke have evaluated the strength of different muscles using the sum of the values, assuming that all muscles had the same weight.[9,19] Another study[18] added together the strength values in 5 major muscle groups in each lower extremity and then subtracted the more-affected side from the less-affected side in 26 subjects with chronic stroke and found a significant correlation with walking speed. Moriello and Mayo[20] developed a position-specific index where the muscles in different positions in both lower extremities were assessed by means of standardized methodology. These indexes were created to provide a single value for the lower extremities.

Assuming that simultaneous activation and coordination of multiple muscles are required to perform a functional movement, a method that combines the values from different muscles into a strength index would give some idea about a more realistic situation. Willen et al[21] elaborated such a method that combined the values from 8 different muscle groups in the lower extremity into a strength index that allowed all the muscle groups to be weighted equally. The strength index was used to evaluate the relation between walking speed in individuals with late effects of polio and in healthy individuals. A nonlinear relation was found in both groups.[21]

The aim of this study was to describe lower extremity strength and its relation to walking performance (speed and distance) in subjects in the later stage poststroke. On the basis of earlier studies,[21,22] we assumed a nonlinear relation.

Methods

Participants

Subjects were recruited from the Rehabilitation Medicine Clinic at Sahlgrenska University Hospital, Gothenburg, Sweden, which they had previously attended as patients. They were first approached by means of a letter that contained study information and then screened in a telephone interview. They had to fulfill the following inclusion criteria: (1) only a single stroke, (2) ≥6 months after stroke, (3) independent walkers for 5 minutes (with or without walking aids), and (4) ≥40 years. Exclusion criteria were severe heart disease; uncontrolled hypertension; lower extremity wounds, pain, or other than stroke-induced gait disability; and inability to follow instructions.

Data from 41 subjects (31 men and 10 women) were used in the study. The mean age of the men was 59±6 years (40−68) and of the women 61±4 years (53−66). The time from stroke onset was 53±36 months (7−159). The stroke was classified as ischemic in 27 subjects and hemorrhagic in 14 subjects. The predominant side of weakness was the right side in 20 subjects and the left side in 21. The usual assistive devices were used by 14 subjects during walking (wheeled walker, n=1; cane, n=5; crutch, n=1; ankle foot orthosis, n=2; cane+ankle foot orthosis, n=5). Motor function in the affected lower extremity according to the Fugl-Meyer scale[23] was a median of 28 (range 13−34), where the maximum score of 34 indicates normal movement control in the affected side compared with the nonaffected side.

List of abbreviation:

6MWT 6-minute walk test

Of the 41 participants, a total of 8 subjects participated in another study at our research department, but no data were collected regarding the Fugl-Meyer scale and they did not perform the 6MWT.

An urban population sample (n=144) was used as a reference group.[21,24] The group consisted of men (n=69) and women (n=75) between 40 and 79 years old, and all resided in the same recruitment area as the stroke subjects.

The study was approved by the Ethics Committee of the University of Gothenburg, and all subjects provided informed written consent.

Evaluations

The stroke subjects were assessed twice over the course of 2 weeks on separate days. In the first visit, walking performance[13,14] was evaluated by a physiotherapist at the Rehabilitation Clinic and the second visit was held at a laboratory, where a muscle strength test was performed by the research nurse and the same physiotherapist.

Muscle strength measurements

Measurements were made on a Biodex Multi-Joint System 3 PRO dynamometer.[a] The equipment was calibrated before testing. The subject was seated comfortably with his or her back against a backrest. A seatbelt was strapped around the shoulders, waist, and thigh to avoid unwanted movements. Before each measurement, the full range of motion was set, the subject's lower extremity was weighed, and the Biodex software corrected the data to account for the influence of the gravity torque on the data. The lower extremity was adjusted to the actuator with the axis of movement adjusted to the center axis of the knee joint. Warm-up submaximal exercises were performed on a bicycle ergometer for 5 minutes before the muscle test. The test order was randomized for the paretic and the nonparetic lower extremity to exclude learning effects. Maximal isokinetic muscle strength (in Newton meters) was measured at a velocity of 60°/s during concentric muscle action of knee extensors and knee flexors for both lower extremities, as previously suggested.[25-27] The peak isometric strength of foot dorsal flexors and plantar flexors at a 30° angle of knee flexion and a 0° ankle angle was also measured. During the test, all subjects were given visual feedback from the system's monitor. They were also verbally encouraged by the examiner to make their maximal effort. Test values were compared with those in the healthy reference group and expressed as a percentage of control values in that group.[24]

Strength testing in stroke populations has been shown to be reliable and valid as an outcome measure in clinical trials.[26]

Strength index

The calculation of the strength index was based on a previous study.[21] The values from the strength measurements were transformed into a *strength index* representing all 8 measurements, allowing all muscle groups to be equally significant.

A factor for each muscle group was constructed by giving the strongest muscle group (knee extension 60°/s) a factor of 1; the other muscle groups' factors corresponded to the ratio between the average muscle strength of the healthy individuals and their knee extensor muscle strength. The same factors were used for both groups.

The index was represented by the equation: *1×knee extension right and left+2.2×knee flexion right and left+1.5×foot plantar flexion right and left+4.5×foot dorsal flexion right and left.* The